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THE VIRGINIA
JOURNAL OF SCIENCE

VOL. 9, NEW SERIES JULY, 1958 No. 3

# The Comparison of the Sensitivities of Similar Experiments[1]

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## INTRODUCTION

In the subjective testing of foodstuffs no natural unit of measurement is available and it is common practice to use ranking methods or to construct a scoring scale on which the flavor and quality of food items are "measured" through the opinions of judges. The problem of comparing the sensitivities of such taste panel experiments that have been based on different scoring techniques or have been conducted by different judges is then raised.

Cochran (1943) discussed the problem of comparing different scales of measurement in a paper in which he confined his attention to the case in which all scales measure the same experiment. Assuming that analysis of variance techniques were applicable, he observed that a comparison of the sensitivities of two scales should depend both on the experimental errors associated with them and on the magnitudes of the treatment effects in the scales. Hence it was suggested that a comparison of scales should depend on a test of significance of the hypothesis that the parameters of two noncentral variance ratios were equal. Generalizing Cochran's concept of comparing scales of measurement, Schumann and Bradley (1957 a,b) have developed means of comparing the sensitivities of two identically designed independent experiments. In this paper we give the principal results obtained in the development of the theory and consider tests of significance with applications in various fields of research indicated.

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1. A resume of original papers published in Annals of Mathematical Statistics 28(4), 1957 and Biometrics 13(4), 1957 but with a new example.

2. Now with the Department of Statistics, Stellenbosch University, Stellenbosch, South Africa.

Editor's Note: For this research, D. E. W. Schumann and R. A. Bradley were awarded the J. Shelton Horsley Award at the Thirty-fifth Annual Meeting of the Virginia Academy of Science. It is published here upon the request of the editors.

## FORMULATION OF THE PROBLEM

Let F' be a noncentral variance ratio with 2a and 2b degrees of freedom (a and b being integers or half-integers) and parameter of noncentrality $\lambda$. If

$$u' = \frac{2a\,F'}{2b}, \tag{1}$$

then u' has the density function

$$f(u'\,;\,a,\,b,\,\lambda) = \frac{u^{a-1}\,e^{-\lambda}}{(1+u)^{a+b}B(a,b)} \cdot {}_1F_1\left(a+b,\,a;\,\frac{u'\lambda}{1+u'}\right) \tag{2}$$

for $0 \leq u' < \infty$, where B represents the beta function and

$${}_1F_1(a,\,b;\,x) = 1 + \frac{a}{b}\cdot\frac{x}{1!} + \frac{a(a+1)}{b(b+1)}\cdot\frac{x^2}{2!} + \cdots\cdots\cdots\cdots$$

is the confluent hypergeometric fuction. In the usual additive analysis of variance model with "fixed" parameters (Model I), $\lambda = \frac{k}{2\sigma^2}\sum_{i=1}^{t} \tau_i^2$, where k is the number of observations in each treatment mean, $\tau_i$ is the effect of the ith of t treatments such that $\sum_{i=1}^{t} \tau_i = 0$ and $\sigma^2$ is the population error variance. It is obvious that the parameter $\lambda$ is dependent on both the experimental errors and the magnitudes of the treatment effects. When $\lambda = 0$, (2) becomes the density of

$$u = \frac{2aF}{2b} \tag{3}$$

where F is the usual central F-statistic based on 2a and 2b degrees of freedom. Then

$$f(u;\,a,\,b,0) = f(u,\,a,\,b) = \frac{u^{a-1}}{(1+u)^{a+b}B(a,\,b)} \tag{4}$$

for $0 \leq u < \infty$.

Now consider two *similar* experiments, that is, experiments with F-statistics (or F'-statistics) for treatment comparisons based on the same degrees of freedom, say 2a and 2b, and assume the experiments to be independent. The independent statistics $u'_1$ and $u'_2$, as defined above, are then taken to be the appropriate statistics on which to base comparisons of the sensitivities of two scales or experimental techniques. We consider their ratio, say $w' = u'_1 / u'_2$. The null hypothesis of equal sensitivities

will then be equivalent to the hypothesis that $\lambda_1 / k_1 = \lambda_2 / k_2$ where $k_i$ ($i = 1, 2$) is the number of observations in each treatment mean of experiment i and $\lambda_i$ is the corresponding parameter of noncentrality. In this paper we will consider only the distribution of w' when $u_1'$ and $u_2'$ arise from two *identical* experiments i.e. experiments having $k_1 = k_2$. The hypothesis of equal sensitivities will then be that $\lambda_1 = \lambda_2$. While extensions to more general situations have been studied, further work has to be done to prove the accuracy and usefulness of some of the tests of hypotheses suggested for situations where the experiments are not identical or similar.

We shall also indicate how the method for the comparison of the sensitivities of experiments may be used to compare two population multiple correlation coefficients whose sampling distributions are based on regression models.

## DISTRIBUTION THEORY

Given similar experiments in which $u_1'$ and $u_2'$, both with 2a and 2b degrees of freedom, are independent, the marginal distribution of $w' = u_1' / u_2'$ can be obtained from the joint distribution of $u_1'$ and $u_2'$. The distribution of w' is[3]

$$g(w'; a, b, \lambda_1, \lambda_2) = e^{-\lambda_1 - \lambda_2} \sum_r \sum_s \frac{\lambda_1^r \lambda_2^s}{r!\, s!} \frac{(w')^{a+r-1}}{B(a+r, b)\, B(a+s, b)} \cdot H(w'; a, b, r, s), \quad 0 \leq w' < \infty,$$

where $H(w'; a, b, r, s) = H(w') = (w'-1)^{-(2a+2b+r+s-1)} \cdot \int_1^{w'} \frac{(x-1)^{2a+r+s-1} (w'-x)^{2b-1}}{x^{a+b+r}} \, dx.$ (5)

Now H(w') may be written in terms of hypergeometric functions:

3. r and s take all integral values 0, 1, 2, . . . . . , $\infty$ unless otherwise specified.

$$H(w') = B(2a+r+s, 2b) \cdot {}_2F_1\ (a+b+r, 2a+r+s, 2a+2b+r+s; 1-w')$$
$$\text{for } 0 \leq w' \leq 1,$$

$$= \frac{B(2a+r+s, 2b)}{(w')^{2a+r+s}} \cdot {}_2F_1\ (a+b+s,\ 2a+r+s,\ 2a+2b+r+s;\ \frac{w'-1}{w'})$$
$$\text{for } 1 \leq w' < \infty,$$

where ${}_2F_1$ is the hypergeometric function.

When $\lambda_1 = \lambda_2 = \lambda$ we have $g(w'; a, b, \lambda) = e^{-2\lambda} \sum\sum_{rs} \frac{\lambda^{r+s}}{r!\, s!}$

$$\cdot \frac{(w')^{a+r-1}}{B(a+r, b)\ B(a+s, b)} \cdot H(w'; a, b, r, s) \qquad (6)$$

The properties of $g(w'; a, b, \lambda) = g(w')$ have been investigated. This is a density function with $g(0) = 0$ and $g(\infty) = 0$ for $a, b > 1$. In general $g(w')$ is a unimodal distribution with mode between 0 and 1 and median at 1. Furthermore, $g(w'; a, b, \lambda) = g(\frac{1}{w'}; a, b, \lambda)$. The *kth* moment about zero is given by

$$\nu_k' = e^{-2\lambda} \cdot \frac{\Gamma(b+k)\ \Gamma(b-k)}{[\Gamma(b)]^2} \sum\sum_{rs} \frac{\lambda^{r+s}}{r!\, s!} \frac{B(a+k+r, a-k+s)}{B(a+r, a+s)}$$

which is defined for $a, b > k$ only.

On account of the complex nature of the density function of w', a tabulation of the distribution is very nearly impossible wtih ordinary computing facilities. Even with $\lambda_1 = \lambda_2$, a three-parameter classification at each specified level of significance is required. An approximation to the density function was accordingly proposed based on the work of Patnaik (1949). Patnaik essentially approximated the distribution of F' with parameter $\lambda$ and 2a and 2b degrees of freedom by a distribution of $\frac{F}{c}$ with 2a' and 2b degrees of freedom, where $c = \frac{a+\lambda}{a}$, $a' = \frac{(a+\lambda)^2}{a+2\lambda}$ and F has the distribution of a central variance ratio. Following Patnaik's method, we approximate $F_i'$ $(i = 1, 2)$ by $\frac{F_i}{c_i}$ or $u_i'$ by $\frac{u_i}{c_i}$ where $u_i'$ and $u_i$ are defined in (1) and (3) respectively. When we have similar ex-

periments and $\lambda_1 = \lambda_2 = \lambda$, the ratio $w' = u'_1 / u'_2$ is approximated by $w = u_1 / u_2$ with $2a' = \frac{2(a+\lambda)^2}{a+2\lambda}$ and 2b degrees of freedom (the equivalent scale factors c cancel when the ratio is considered).

For the distribution of w, we have $\lambda_1 = \lambda_2 = 0$ and the density function of w which approximates (6) can quite easily be obtained by setting $\lambda = 0$ and writing a' for a in (6). This gives

$$g(w; a', b) = \frac{w^{a'-1} H(w; a', b)}{[B(a', b)]^2}, \quad 0 \le w < \infty, \tag{7}$$

where $H(w;a',b) = H(w)$

$$= \int_0^\infty y^{2a'-1} [(1+wy)(1+y)]^{-(a'+b)} \, dy.$$

In general the lower moments of the density functions (6) and (7) tend to equality for large degrees of freedom, that is, large a' and b.

The distribution function of w',

$$G(w'_0; a, b, \lambda) = \int_0^{w_0} g(w'; a, b, \lambda) \, dw,$$

may be approximated by the distribution function

$$G(w_0; a', b) = \int_0^{w_0} g(w; a', b) \, dw = \frac{1}{[B(a', b)]^2} \int_0^\infty y^{a'-1} (1+y)^{-(a'+b)} \frac{(w_0 y)^{a'}}{(1+w_0 y)^{a'}} \cdot \left[ \frac{1}{a'} - \frac{(b-1) w_0 y}{(a'+1)(1+w_0 y)} + \cdots\cdots\cdots\cdots\cdots \right] dy$$

with $a' = \frac{(a+\lambda)^2}{(a+2\lambda)}$ as above. The suitability of this approximation

was determined on the basis of comparing a limited number of values of $G(w_0';a,b,\lambda)$ and $G(w_o;a',b)$.

Tables of values of $w_o$ for which $G(w_o;a,b) = 0.95$ were prepared and were published by Schumann and Bradley (1957a). Additional tables are in preparation. The tables are essentially triangular since it is known that $G(w_o;a,b) = G(w_o;b,a)$.

## TESTS OF HYPOTHESES ON SENSITIVITY

In the comparison of the sensitivities of identical experiments we shall be interested in a test of the null hypothesis $H_o: \lambda_1 = \lambda_2 = \lambda$ against (i) a two-sided alternative $H_a: \lambda_1 \neq \lambda_2$, or (ii) a one-sided alternative $H_a: \lambda_1 > \lambda_2$. The test statistic is $w' = u_1' / u_2' = F_1' / F_2'$ $F_1'$ and $F_2'$ being independent noncentral variance ratios with parameters $\lambda_1$ and $\lambda_2$ respectively and both with 2a and 2b degrees of freedom. The test procedure is for (i) to reject $H_o$ with significance level $2\alpha$, when $w' > w_o'(\alpha)$ or $\frac{1}{w'} > w_o'(\alpha)$ and for (ii) to reject $H_o$ with significance level $\alpha$ when $w' > w_o'(\alpha)$. The other one-sided alternative $H_a: \lambda_1 < \lambda_2$ is included under (ii) by interchange of definitions of $F_1'$ and $F_2'$. The cited table is used to obtain approximations of $w_o'(\alpha)$ for $\alpha = 0.05$. We compute a' using a and an estimate of $\lambda$ and interpolate (linearly) in the table to obtain the value of $w_o$ that can be used as an approximation to $w_o'(0.05)$.

It is apparent that $\lambda$ enters into the calculations as a nuisance parameter. Fortunately $w_o'(\alpha)$ is not greatly affected by variations in $\lambda$ and consequently it should have little effect in applications if we enter the tables using a value of $\lambda$ somewhat different from its true (unknown) value. It is satisfactory to take $\lambda$ as the average of $\lambda_1$ and $\lambda_2$, which may be found through equating well known expectations of mean squares

to observed mean squares in the analysis of variance for the two identical experiments.

The basic steps in a test of hypothesis on sensitivity can be summarized as follows:-

1. Do analyses of variance for both experiments yielding F'-statistics valid for treatment comparisons, each with 2a and 2b degrees of freedom.

2. Estimate $\lambda_1$ and $\lambda_2$ pertaining to the two experiments and take $\hat{\lambda} = \frac{1}{2}(\hat{\lambda}_1 + \hat{\lambda}_2)$ as an estimate of $\lambda$, where $\hat{\lambda}_i$ $(i = 1, 2)$ is the estimate of $\lambda_i$. In Model I of the analysis of variance we take $\hat{\lambda}_i = a\left[\frac{s_t^2}{s_e^2} - 1\right]$

where $s_t^2$ and $s_e^2$ are respectively the mean squares for treatment and error of experiment i.

3. Formulate the null hypothesis $H_o: \lambda_1 = \lambda_2 = \lambda$ and use $\hat{\lambda}$ for the unspecified $\lambda$ in subsequent calculations.

4. Decide on the significance level $a$ to be used. (At present we are limited to $a = 0.05$ since that table is the only one yet available to readers of this paper.

5. Calculate $w' = F_1'/F_2'$ and $a' = \frac{(a+\hat{\lambda})^2}{a+2\hat{\lambda}}$ using $\hat{\lambda}$ obtained in Step 2.

6. Enter the table with a' for a and with b and obtain $w_o(0.05)$ by using linear interpolation. Compare w' with $w_o(0.05)$ and accept or reject $H_o$ in accordance with the procedure explained above with $w_o(0.05)$ substituted for $w_o'(0.05)$.

## AN ILLUSTRATIVE EXAMPLE

As a numerical example, we consider data obtained by Kauman, Gottstein, and Lantican (1956) relating to an experiment in which subjective quality evaluations of twenty sheets of dried veneer were made

using two methods and three judges. Two schemes were used to evaluate quality of sheets of veneer and they were designated as *numerical* and *subjective* although both were considerably subjective. In the numerical scheme, various types of degrade were listed with numerical scores for the severity of the degrade and weights given for use in combining degrade scores to obtain a quality score. A quality score of fifty was very bad and the maximum attainable; a quality score of zero indicated a sheet free from degrade. In the subjective scheme, quality ratings were assigned on a 0 - 8 scale with 0, excellent and 8, very bad.

TABLE I

ANALYSES OF VARIANCE FOR QUALITY RATINGS*

| Factor | Degrees of Freedom | Numerical Scheme | | Subjective Scheme | |
|---|---|---|---|---|---|
| | | Sum of Squares | Mean Square | Sum of Squares | Mean Square |
| Sheets (S) | 19 | 12826.16 | 675.1 | 336.90 | 17.73 |
| Observers (O) | 2 | 170.72 | 85.36 | 3.70 | 1.852 |
| Repetitions | 3 | 168.13 | 56.04 | 0.61 | 0.2042 |
| Interaction (SO) | 38 | 823.61 | 21.67 | 30.12 | 0.7928 |
| Error | 57 | 595.37 | 10.45 | 22.13 | 0.3884 |

* A reproduction of part of Table 6, Kauman, Gottstein, and Lantican (1956), page 148.

Twenty selected sheets of veneer were evaluated by three observers, twice with each scheme, and repeat observations were spaced by several days with the order of presentation of the sheets changed. Successive evaluations of the sheets by the observers will be taken to be independent. The more sensitive evaluation scheme will be defined to be the one exhibiting greater quality differences among the twenty sheets of veneer. Complete tables of scores are given in the reference; we repeat the analyses of variance in Table I.

The steps in the comparison of the sensitivities of Method 1 (the numerical scheme) and Method 2 (the subjective scheme) to differences in quality of the test sheets of veneer then give the following results:

1. $F'_1 = 64.60$, $F'_2 = 45.65$, $a = 9.5$ and $b = 28.5$
2. $\lambda_1 = 9.5(64.60 - 1) = 604.2$, $\hat{\lambda}_2 = 9.5(45.65 - 1) = 424.2$ and we take $\hat{\lambda} = \frac{1}{2}(604.2 + 424.2) = 514.2$.
3. $H_o: \lambda_1 = \lambda_2 = \lambda$ and $H_a: \lambda_1 \neq \lambda_2$.
4. Take the significance level as 0.10 i.e. $\alpha = 0.05$.
5. $w' = \dfrac{64.60}{45.65} = 1.42$ and $a' = \dfrac{(a+\lambda)^2}{a+2\lambda} = 264.2$.
6. Enter the table in either cited references [Schumann and Bradley (1957 a,b)] with $a = 264.2$ and $b = 28.5$ or $a = 28.5$ and $b = 264.2$. We find that $w_o(0.05) \approx 1.85$.. Neither $w'$ nor $\dfrac{1}{w'}$, is significant in comparison with $w_o(0.05)$, the approximation of $w'_o(0.05)$, and we have no reason to reject $H_o$. It does not appear that the two methods of evaluating quality of veneer differ much in sensitivity to veneer-sheet differences. We are in accord with the authors (Kauman et al) who state: "The present experiment has shown that the subjective evaluation can yield results of an accuracy approaching that of the numerical scheme, although the accuracy of the latter was slightly superior".

## TESTS OF HYPOTHESES ON MULTIPLE CORRELATION COEFFICIENTS

Consider the usual multiple regression equation with "fixed" or non-stochastic independent variables of the form

$$y = c_o + c_1 x_1 + c_2 x_2 + \cdots\cdots + c_p x_p .$$

If R is the multiple correlation coefficient based on N sets of observations $(y_i, x_{1i}, \ldots\ldots, x_{pi})$, $i = 1, \ldots, N$, it is well known that $u' = \dfrac{R^2}{1-R^2}$ has the distribution $f(u'; a, b, \lambda)$ defined in (2) with $a = p/2$,

$b = (N-p-1)/2$, and

$$\lambda = \frac{(a+b)\rho^2}{(1-\rho^2)} = \frac{(N-1)\rho^2}{2(1-\rho^2)} , \quad (8)$$

where $\rho$ is the population multiple correlation coefficient estimated by R. Hence, if we have two independent corresponding multiple correlation coefficients $R_1$ and $R_2$ each based on p nonstochastic independent variables and N observation vectors, the distribution of $w' = R_1^2(1-R_2^2) / R_2^2(1-R_1^2)$ is given by (6) when $\rho_1 = \rho_2 = \rho$, with a, b, and $\lambda$ defined by (8). The theory and test procedures developed for a comparison of the sensitivities of identical experiments can therefore, be applied to compare multiple correlation coefficients. It must be observed that this does not apply to multiple correlation coefficients based on models in which it is assumed that the variables $y, x_1, x_2, \ldots\ldots, x_p$ follow a multivariate normal distribution.

To compare two multiple correlation coefficients in independent and identical experiments, we test the null hypothesis $H_o: \rho_1^2 = \rho_2^2 = \rho^2$ against the alternative (i) $H_a: \rho_1^2 \neq \rho_2^2$ or (ii) $H_a: \rho_1^2 > \rho_2^2$. The test statistic is $w' = R_1^2(1-R_2^2)/R_2^2(1-R_1^2)$ with both $R_1$ and $R_2$ based on p independent variables and N observation vectors. The test procedure is the same as for tests on the sensitivities of identical experiments given above.

The basic steps to be taken are:-

1. Obtain the multiple correlation coefficients, $R_1$ and $R_2$, for the two experiments. Take $a = p/2$ and $b = (N-p-1)/2$.

2. Estimate $\rho_i^2$ $(i = 1, 2)$ using $\hat{\rho}_i^2 = 1 - \dfrac{(a+b)(1-R_i^2)}{b}$ as an

estimate of $\rho_i^2$, in the manner proposed by Snedecor (1950, p. 348). Take $\hat{\rho}^2$ to be the mean of $\hat{\rho}_1^2$ and $\hat{\rho}_2^2$.

3. Formulate the null-hypothesis $H_o: \rho_1^2 = \rho_2^2 = \rho^2$ using $\hat{\rho}^2$ for $\rho^2$, and the suitable alternative.

4. Decide on the significance level to be used.

5. Calculate $w' = R_1^2(1-R_2^2) / R_2^2(1-R_1^2)$ and

$$a' = \frac{(a+\hat{\lambda})^2}{a+2\hat{\lambda}} = \frac{[p+(N-p-1)\hat{\rho}^2]^2}{2(1-\hat{\rho}^2)[p+(2N-p-2)\hat{\rho}^2]}$$

6. Obtain $w_o(\alpha)$ as an approximation to $w'_o(\alpha)$ from the cited table with $\alpha = 0.05$ by entering the table with $a'$ for a and $(N-p-1)/2$ for b. Compare $w'$ with $w_o(\alpha)$ and accept or reject $H_o$.

## CONCLUSION

In this paper we have indicated methods of comparing the sensitivities of experiments and multiple correlation coefficients. These methods are applicable in different fields of research. In taste testing experiments the procedures discussed here may be applied to compare the sensitivities of two scoring scales employed, two taste panels, two methods of preparation of test items or two environmental situations during testing, provided data are available from identically designed experiments in a form suitable for analysis of variance. In agronomy, especially in pasture experimentation where different (but comparable) methods of measuring the yields of forage mixtures are used, the sensitivities of the techniques relative to the differences between forage characteristics observed, may be compared. In electronics it may be possible to compare experiments based on accelerated life tests with experiments based on normal life tests, or to compare the sensitivities of alternative means of conducting accelerated life tests. In physics and chemistry two similar experiments might be conducted and their sensitivities compared to determine which method of experimentation is to be used in routine experiments.

The methods of comparing the sensitivities of experiments are applicable in the case of independent experiments with F ratios based on the same degrees of freedom and with the same number of repetitions in each treatment mean. There are some situations wherein the sen-

sitivities of experiments that do not meet the requirements of similarity should be compared. Some suggestions have been made for tests of hypotheses applicable in these cases but their appropriateness must still be investigated.

The extension of tables for the tests of significance outlined in this paper is being undertaken and tables of the upper 2.5%, 1% and 0.05% points of the distribution function $G(w_o; a, b)$ are under construction.

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# Tetrahymena rostrata as a Facultative Parasite In the Grey Garden Slug

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Two species of holotrichous ciliates have been designated as facultative parasites in the grey garden slug, *Deroceras agreste* L. (*Deroceras reticulatum* Muller). Reynolds (1936) reported *Colpoda steini* from the respiratory chamber and liver tubules of slugs inhabiting the "grounds" of the University of Virginia. Warren (1932) described *Paraglaucoma limacis* from slugs in the vicinity of Pietermaritzburg, Natal. After studying a ciliate found in the grey garden slugs collected from Washington and Oregon, Kozloff (1946) concluded that this protozoon was identical with *Paraglaucoma limacis* of Warren and that both should be included in the genus *Tetrahymena* as *Tetrahymena limacis*. Borden (1948) reported both *Colpoda steini* and *T. limacis* from the slugs collected from the "grounds" of the University of Virginia.

*Tetrahymena rostrata* (Kahl, 1926) Corliss was described as a free living ciliate from European and American mosses. Its role as a facultative parasite was first reported in New Zealand (Stout, 1954) where it was found to infect enchytraeid worms. The second such case of parasitism was discovered by the present writer in *Deroceras reticulatum* collected from Culpeper, Virginia in 1955.

## MATERIALS AND METHODS

Silver impregnation (Corliss, 1953a) was employed to determine the important pellicular structures of *Tetrahymena rostrata*. Delafield's haematoxylin was used as a nuclear stain. Studies of the living ciliates were made with both phase and ordinary light microscopy. Bacteria-free clone cultures of the ciliate were established in medium consisting of two per cent proteose-peptone plus one-tenth per cent of liver fraction L.

## OBSERVATIONS AND RESULTS

While examining a grey garden slug for facultative parasites, large protozoan cysts were found in the fresh feces. These cysts were few in number but appeared repeatedly, even after weeks of feeding on washed lettuce. Excystment took place in tap water and the ciliates were cultured on bacterized meat culture. Subsequent morphological studies were made and the ciliate identified as *Tetrahymena rostrata*. In general, the

morphological features of the slug parasite agreed with earlier descriptions of *T. rostrata* but in addition a single caudal cilium was noted. This cilium appeared about twice the length of a regular body cilium and did not beat as the other cilia but often seemed to trail behind. It was not a "stiff-bristle" but was seen to bend in body movements.

A clone culture was established in axenic medium (Holz and Thompson, 1955). In experimental infections of various animals using axenic strains of the genus *Tetrahymena*, *T. rostrata* was able to infect Betsy beetles, wood feeding roaches, dragonfly nymphs, and tent caterpillars when injected into the body cavity.

When morphological studies were made on *T. rostrata* cultured in axenic medium, a variation in ciliary rows was noted. Meridional counts made from bacterized cultures ranged from 28 to 32 with a mode of 30. From axenic cultures the meridional counts ranged from 27 to 48 with a mode of 33. Many bizarre ciliates appeared here and the ciliary meridians were often not oriented in the usual manner but appeared somewhat as altitude contours of a mountain peak.

## DISCUSSION

Stout (1954) in his description of *T. rostrata* from enchytraeid worms gave the first good morphological description of the ciliate. But he failed to identify the single caudal cilium or the third buccal membranelle which were found in the slug parasite. These structures were later observed by the present writer in a culture of *T. rostrata* sent by Dr. Stout from the enchytraeid infections.

Borden (1948) was probably the first investigator to observe *T. rostrata* as a facultative parasite. In her study she reported *T. limacis* from 8 of the 117 slugs examined. She reported that ciliates in old cultures "in some cases acquired a cyst wall, and finally died. Division was observed in some of the cysts". Since *T. limacis* has never been known to produce cysts and since *T. rostrata* is the only species of the genus that forms both resting and reproductive cysts, it is very likely that this species was present in some of Borden's cultures.

Stout supported Corliss (1953b) in declaring *T. rostrata* an obligate histophage but since the ciliate has been established in both axenic and bacterized cultures this can no longer be supported. Also the present writer observed this ciliate to feed on algae.

Kozloff (1956) noted a variation in meridian counts of *T. limacis* grown in axenic medium from those found as facultative parasites in the slug. But here only a decrease in number was reported. Since this

phenomenon was also noted for *T. rostrata*, future protozoan descriptions should not base meridian counts solely from axenic cultures.

The ability of *T. rostrata* to establish experimental infections in the body fluids of various insects suggests that in nature insects may often serve as natural hosts for this ciliate.

## SUMMARY

Large protozoan cysts were found repeatedly in the feces of *Deroceras reticulatum* even after weeks of feeding on washed lettuce. Morphological studies were made and the ciliate identified as *Tetrahymena rostrata*, normally a free living protozoon.

Clone cultures were established in axenic medium. Later morphological studies of ciliates from axenic cultures revealed a variation in the number of meridians from ciliates cultured on bacterized medium.

*T. rostrata* was experimentally established as a parasite in the body fluids of certain insects.

## ACKNOWLEDGMENT

This investigation was aided by a National Science Foundation Grant for summer research conducted at the Mountain Lake Biological Station, Mountain Lake, Virginia.

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# The Ovule and Embryo Sac of Galax Aphylla

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*Galax aphylla* L. is a monotypic herbaceous perennial of the family Diapensiaceae. According to Baldwin (1941), it occurs naturally from northern West Virginia and northwestern Maryland to central Georgia and central Alabama and from eastern Virginia to central Tennessee.

According to Gray (1873), Lindley established the order Diapensiaceae in 1836. A survey of the literature published since that time reveals no paper which describes ovule and embryo sac development in *Galax*.

## MATERIALS AND METHODS

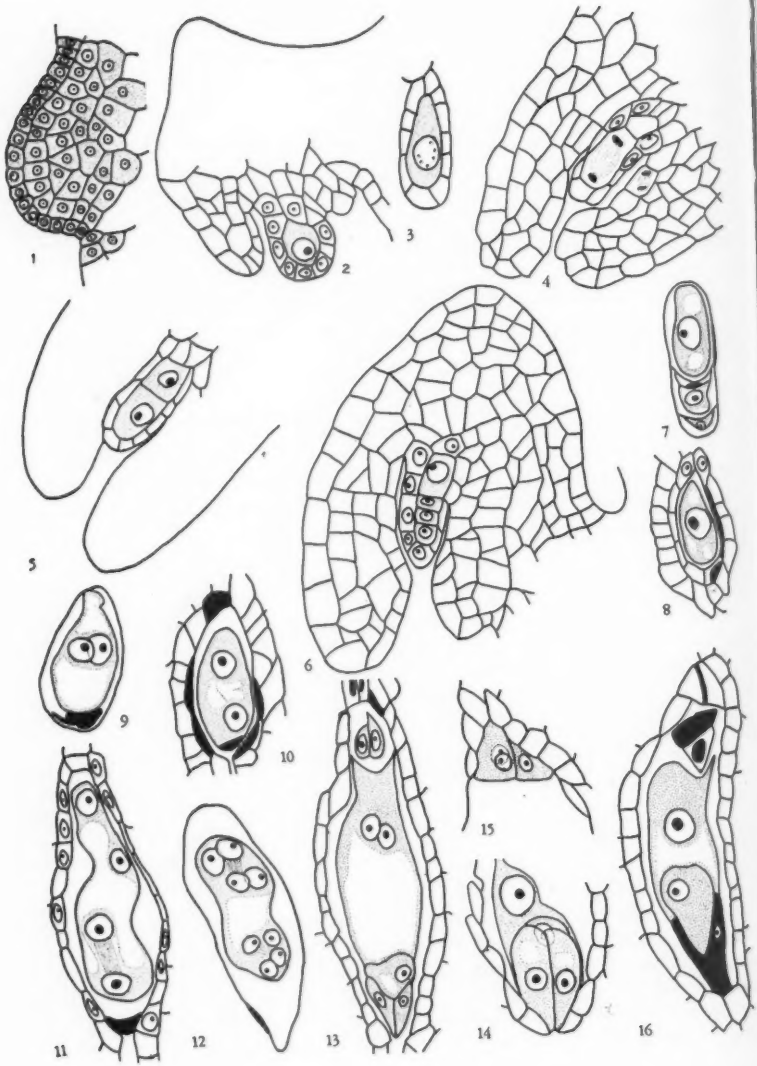
Buds and flowers were fixed in the field in a formalinaceto-alcohol solution. Sections were cut at 22-30 $\mu$ and stained in safranin and fast green. Drawings were made with the aid of a camera lucida, each from a single section.

## OBSERVATIONS

The pistil of *Galax aphylla* is three-carpellate. In each of the three locules, the placenta is axile in position, the ovules are few to numerous, and ovule arrangement on the placentae is somewhat varied, so that only a small number of sections are available for development study in longitudinal sections of the pistil.

The ovule arises as a protuberance of meristematic cells from an axile placenta of an immature flower (fig. 1.) As it becomes more prominent, the young ovule turns as a result of unequal growth. At this stage the single primordial integument of the ovule emerges (fig. 2). This single integument, which is from 4-6 cells in thickness, soon envelops the tip of the nucellus except for a small opening, the micropyle (fig. 4-6).

Just prior to or simultaneously with integument formation the single subepidermal archesporial cell becomes differentiated. The archesporial cell is larger than the surrounding nucellar cells and contains a large nucleus and nucleolus (fig. 2). As the archesporial cell, which is polygonal in shape and enlarges mostly by elongation parallel to the long axis of the ovule, becomes the megaspore mother cell, the ovule approaches the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anatropous condition (fig. 2-6). The first meiotic division of the megaspore mother cell forms two dyad cells (fig. 4-5). The megaspore mother cell upon completion of the second meiotic division forms four megaspores arranged linearly (fig. 6). The three micropylar megaspores disintegrate leaving the chalazal one as the functional megaspore. The disintegrated spores are characterized by a collapse of the cell walls, by a dissolution of the nuclei, and by a deep staining reaction of the remaining cytoplasm (fig. 7-8).

During enlargement and elongation of the functional megaspore, the three micropylar megaspores disintegrate and a vacuole appears at each end of the cell with the nucleus remaining in the center (fig. 7). Development into an embryo sac begins when this centrally located nucleus divides forming two daughter nuclei (fig. 9). The migration of the two small vacuoles and their fusion between the nuclei results in a two-nucleated embryo sac in which one nucleus is located at the micropylar end of the sac and the other at the chalazal end (fig. 10). As the embryo sac continues development, the nucellus disintegrates and disappears except for occasional disintegrated cells which can be seen due to their deep staining reaction (fig. 10). A division of the two nuclei occurs and a four-nucleated sac is formed (fig. 11). Each of the four nuclei then divides giving rise to an eight-nucleated sac (fig. 12). The eight nuclei are arranged in quartets, a micropylar one and a chalazal one. Shortly after development reaches the eight-nucleated stage, one nucleus from each quartet migrates toward the center of the sac. The formation of the mature embryo sac, which includes an egg and two synergid cells, the egg apparatus at the micropylar end, two centrally located polar nuclei, and three antipodal cells at the chalazal end, is now completed (fig. 13-15).

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Fig. 1-16. x 166.—Fig. 1. Ovule arises as a protuberance of meristematic cells. Fig. 2. Integument becomes differentiated; nucellus with archesporial cell. Fig. 3-5. First division of the megaspore mother cell showing formation of dyad cells. Fig. 6. Anatropous ovule; nucellus with four megaspore in linear arrangement. Fig. 7-8. One-nucleated embryo sacs; megaspore disintegration. Fig. 9-10. Two-nucleated embryo sacs. Fig. 11. Four-nucleated embryo sac. Fig. 12. Eight-nucleated embryo sac. Fig. 13. Seven-celled, eight-nucleated embryo sac showing the three cells of the egg apparatus, the two polar nuclei, and two of the three antipodal cells. Fig. 14. Portion of embryo sac showing egg apparatus and secondary polar nucleus. Fig. 15. Portion of embryo sac showing arrangement of the three antipodal cells. Fig. 16. Zygote and primary endosperm nucleus; note antipodal and synergid disintegration.

Shortly after the mature embryo sac is formed, the polar nuclei fuse to form a large secondary polar nucleus (fig. 14). After fertilization occurs, the three antipodal cells and the two synergid cells disintegrate (fig. 16).

Development, therefore, in *Galax aphylla* follows the *Polygonum*-type. A comparison between ovule and embryo sac formation in *Galax aphylla* and *Diapensia lapponica*, as described by Samuelsson (1913), reveals that they closely parallel one another.

## SUMMARY

The development of the anatropous ovule and the *Polygonum*-type embryo sac of *Galax aphylla* is described. A single subepidermal archesporial cell, surrounded by a single evanescent layer of nucellar cells, after lengthening parallel to the long axis of the ovule functions as the megaspore mother cell. The four megaspores formed from the megaspore mother cell are arranged linearly. As the chalazal megaspore develops into a seven-celled, eight-nucleated embryo sac, the three micropylar megaspores disintegrate.

## ACKNOWLEDGMENTS

The author is indebted to Dr. E. M. Betts of the Miller Biological Laboratories, University of Virginia for suggesting the problem and to the National Science Foundation for financing the work.

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# Some Curious Analogies in Explorers' Preconceptions of Virginia

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Early observers made ample errors in interpreting Virginia's natural landscapes after they had viewed them, but even more curious were the views they held concerning this land before they arrived. The English, who had learned precious little about the New World after almost a century of Spanish voyaging, had to rely upon rumors, fanciful *mappaemundi*, and analogies from known lands for their information about temperate America. Lacking real knowledge, the English confidently presumed that the climate, topography, and mineral resources of North America would be the same as those of the same latitudes in Eurasia and in Spanish South America.

Still untested by adequate observation, the classical notion of rigid latitudinal zonation of climates was regarded as immutable by Europeans. Even before Raleigh's first expedition to Roanoke Island returned to England, Richard Hakluyt, the famous English arm-chair "geographer" (really just a compiler of travel narratives), prepared his "Discourse of western planting" which stated that Mediterranean crop plants could easily grow in the same latitudes in North America (Taylor, 1935). Thomas Hariot, the accurate scientific observer, spent the winter of 1585-1586 in what is now northeastern North Carolina and southeastern Virginia, but he reported only that the climate was "answerable to . . . the South part of Greece, Italy, and Spaine." (Quinn, 1955). Thus the original belief that Virginia's climate should be the same as that of the Mediterranean lands because of the sameness of latitude was reinforced by a veracious traveler who had wintered there. John Smith was among the first to modify the view that lands in the same latitude necessarily have the same climate when he said concerning Virginia: "The sommer is hot as in *Spaine*; the winter colde as in *Fraunce* or *England*" (Smith, 1910). However, Virginia has humid, not dry Mediterranean, summers, and even though the average January (coldest month) temperatures at Jamestown and London are about the same, nevertheless the former has a greater range and experiences more frequent change. When the more northerly colonies of New England and the Middle Atlantic region were settled, their cold winters could not be compared at all with England's,

and yet the homeland lay in higher latitudes than all the American colonies. The colonists could simply not understand the climatic differences between east coast and west coast locations.

The Jamestown explorers set out with some odd notions about the size and shape of the North American continent. Hope apparently still persisted in finding the "Sea of Verrazano" not far from the Atlantic seaboard (Cumming, 1938). The 1607 colony was instructed by the London Company to commence exploration immediately to reach this sea not far to the westward. The explicit instructions read as follows:

> You shall do your best endeavour to find out a safe port in the entrance of some navigable river . . .
>
> You must observe if you can, whether the river on which you plant doth spring out of mountains or out of lakes. If it be out of any lake, the passage to the other sea will be more easy, and (it) is like[ly] enough, that out of the same lake you shall find some spring which run (s) the contrary way towards the East *India* Sea; for the great famous rivers of *Volga, Tan (a) is* [Don], and *Dwina* have three heads near joyn (e) d; and yet the one falleth into the *Caspian* Sea, the other into the *Euxine* [Black] Sea, and the third into the *Paelonian* [White] Sea (Smith, 1910).

These instructions show that the English believed in the close proximity of the "East India Sea" to the Atlantic in the latitude of Chesapeake Bay and that they further hoped that the river systems of North America were similar to those of Russia where rivers whose sources are close together flow in different directions and provide easy transport from sea to sea. They apparently believed that the continents were so much alike in their natural features that such a prediction about North America was justified. The men of the 17th century were naturally unaware that the Russian situation was largely the result of heavy continental glaciation, a configuration without parallels in Virginia (Taylor, 1934).

William Berkeley, governor of Virginia from 1642 to 1652 and from 1660 to 1677, was from the beginning of his term interested in the fur trade and also in the possibility of finding a water route to Asia. In 1669 he wrote the following to Lord Arlington:

> I did this last spring resolve to make an Essay to doe his Majestie a memorable service which was in the Company of Two hundred Gent who had engaged to goe along with me to find out the East India sea, and we had hopes that in our Journy we should have found some Mines of silver; for certaine it is that the spaniard in

the same degrees of latitude has found many. But my Lord unusual and continued Raynes hindred my intentions (Alvord and Bidgood, 1912).

Here Berkeley is not only stating his belief in the nearness of the East India Sea but also shows that he subscribed to the time-honored notion that lands in the same latitudes possessed identical mineral resources. Earlier, in 1616, John Smith had also voiced this view when he said, concerning New England: "Southward, in the same height [latitude], is the richest of gold Mynes, *Chily* and *Baldiuia*, and the mouth of the great Riuer of *Plate*, &c." (Smith, 1910).

Another analogy with South America was drawn by John Lederer, the mysterious German physician whom Berkeley allowed to make three trips westward from the Virginia settlements in 1669 and 1670 with the intention of finding the East India Sea but who never went beyond the Blue Ridge. Lederer embellished his account with tales of pearls and peacocks, and, although he never even penetrated the Great Valley, concluded that the "Indian ocean" was to be found just on the other side of the Appalachians. He stated:

> I am brought over to their opinion who think that the Indian ocean does stretch an arm or bay from California into the continent as far as the Apalataean mountains, answerable to the Gulfs of Florida and Mexico on this side. Yet I am from believing with some, that such great and navigable rivers are to be found on the other side the Apalataeans falling into the Indian ocean, as those which run from them to the eastward. My first reason is derived from the knowledge and experience we already have of South-America, whose Andes send the greatest rivers in the world (as the Amazones and Rio de la Plata, etc.) into the Atlantick, but none at all into the Pacifique sea. (Alvord and Bidgood, 1912).

Lederer did not realize that the Andes, even though they lie close to the sea, do "send" some rivers down to the Pacific and also that the Appalachians are in no way comparable to the great western cordillera of South America.

These examples demonstrate the inherent pitfalls in the early explorers' attempts to predict what the natural landscapes of unknown lands would be like by analogy with known lands of the same latitude. As the colonists gained in experience they realized that latitude alone is not an indicator of climate—and certainly not of shapes of continents, the nature of river systems, and of the location of mineral bodies.

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# News And Notes

*(Editor's Note: News contributions should be sent to the person whose name appears at the end of the appropriate sections.)*

## MINUTES OF COUNCIL MEETING

Virginia Academy of Science, Richmond, Va., March 8, 1958

The meeting was held at the Rotunda Club in the Hotel Jefferson; it was called to order at 10:40 a.m. by the president.

The following council members were present: William G. Guy; John C. Forbes; Horton H. Hobbs, Jr.; Edward S. Harlow; Charles F. Lane; Lynn D. Abbott; Walter S. Flory, Jr.; Mrs. B. G. Heatwole; Thomas E. Gilmer; Foley F. Smith; William M. Hinton; William B. Wartman, Jr., and Irving G. Foster. Boyd S. Harshbarger and Sidney Negus also attended at the request of President Guy.

The assistant secretary-treasurer read the minutes of the last meeting. After one minor change, they were approved.

The president reported that he had requested Dr. Cooper of Virginia Polytechnic Institute to write a tribute to the late Marcellus Stow, which would be published in the January issue of the Journal. Council endorsed this action taken by the president. *The Seashore Science Center Proposal:* The president reported that no further action had been taken on this proposal.

*Report of the Committee to Survey the Need for Research Funds by Faculty Members of Academic Institutions in Virginia, principally those in Smaller Institutions for Research Projects During the Summer Months:* Dr. Forbes reported that a survey of eleven institutions showed that such a need did exist, with seventy-five persons from ten institutions expressing an interest in securing such funds. He suggested that an initial sum of $25,000 would be needed and that a grant of about $1,000 would enable a faculty member to devote the summer months to a research project. There was considerable discussion as to possible sources of such funds, the procedure to follow in securing these funds and the role the Academy should play in this project. A motion was passed that the president appoint a committee to further pursue this project, especially as to ways and means of securing the necessary funds and the role the Academy should play in the project, this committee to submit a report to the Council.

*Report of the Treasurer and the 1958 Budget:* In his report the

treasurer stated that the auditor had not completed the tax report and therefore had not submitted a statement for the audit of the treasurer's records for the two-year period ending December 31, 1957. As a consequence, Council delayed action on the question of an annual or a biannual audit of the treasurer's records. Walter Flory suggested that a monetary savings could be effected by an annual review of the treasurer's records by all Academy committees as was done for the year 1956. In view of the anticipated increase in postage rates, the treasurer requested that the budget item "postage, addressograph service and section expense" be increased from $250 to $300.

Charles F. Lane, Managing Editor of the Journal, reported on the financial status of the Journal. Again, he reported that the increasing costs of publication of the Journal without increased revenue was rapidly exhausting the reserve funds. He stressed the necessity of either curtailing the material published in the Journal, thereby reducing publication costs, or an increase in Journal funds. Among the suggestions proposed for alleviating this condition were: (1.) Discontinue publishing the General Program of the Annual Meeting in the Proceedings, since this is published in the annual April issue. (2.) Reduce the "News and Notes" copy. (3.) Increase the advertising revenue.

The estimated income of the Academy for 1958 would not permit raising the funds allocated to the Journal in the 1958 budget without the possibility of deficit financing. A motion was passed that the 1958 budget be approved as presented by the Finance and Endowment Committee with the provision that should additional funds become available, the budget would be revised accordingly.

A motion was passed that the chairman of the Finance and Endowment Committee be requested to appoint a member of his committee as chairman of the Subcommittee on Business Memberships.

As requested in the minutes of the Finance Committee Meeting on February 20, 1958, a motion was passed approving the appointment of a subcommittee by the chairman of the Finance and Endowment Committee to raise fifteen hundred dollars during the calendar year.

A motion was passed that the president request the Editor of the Journal to present at the next Council meeting suggested ways and means of effecting savings in the printing costs of the Journal.

*Proposal that the Virginia Academy of Science Participate in the Joint Coordinating Committee of Engineering Societies*: The report of Henry Leidheiser and Bernard Niemeier, submitted in writing, recommended "that the V.A.S. not become a charter member of the Joint Co-

ordinating Committee of Engineering Societies but follow its activities closely and join in the group later if the nature of its activities justifies such action." A motion was passed that Council accept the report and its recommendation.

*Report of the Local Arrangements Committee*: Boyd Harshbarger, chairman of the committee, suggested that information on housing accomodations and a brief program of activities, including section meetings, be mailed to the membership as soon as possible.

A motion was passed that the chairman of the Local Arrangements Committee assemble this information and transmit it to the secretary for mailing to the membership.

*Future of the James River Project and Jamestown Festival Project*: The president appointed Foley Smith temporary chairman of the James River Project Committee.

A motion was passed that the Jamestown Festival Committee be abolished and that the activities of this committee be assumed by the Long-Range Planning Committee.

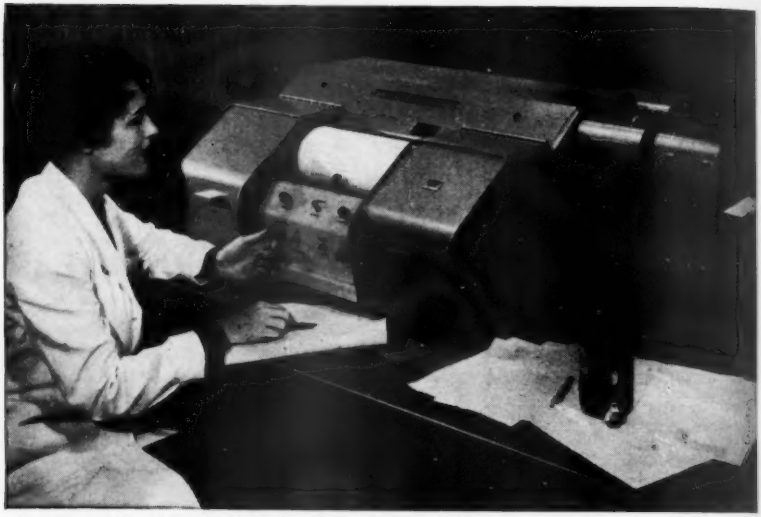
A possible project in science education to be submitted to the Academy Conference for financial support from A.A.A.S. was discussed but the matter was left 'open' pending the submission of any acceptable proposal. The president reported that the secretary had submitted the nomination of the following persons as possible representatives of the Academy at the A.A.A.S. meeting of American scientists to be held at Washington, D. C., on March 15-17: James W. Cole, Jr., Arthur Bevan, and Jesse W. Beams.

The Council members were guests at luncheon of president-elect Forbes and after going on record in expressing their deep appreciation of his generous hospitality, the meeting was adjourned at 2:30 p.m.

—W. B. Wartman, Jr., *Assistant Secretary-Treasurer*

## AGRICULTURAL SCIENCE

C. J. Ackerman, Associate Professor in the Department of Biochemistry and Nutrition, Virginia Polytechnic Institute, participated in the 10th Annual Research Conference sponsored by the Research Advisory Council of the American Meat Institute Foundation and presented a paper on the subject, "Growth Promoting Properties of Meat Meal." Ackerman was one of approximately 15 noted scientists who gave papers at this meeting. Four hundred individuals representing the meat packing industry



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and university and government agencies attended this recent meeting held at the University of Chicago. Ackerman has studied the alleviation of the rat growth depressing effect of the sulfa drugs by meat meal.

John P. Garber, a junior in the Department of Dairy Science, Virginia Polytechnic Institute, received the 1958 Ralston Purina undergraduate award of $500. The award is based on academic proficiency, need, and extra-curricula activities.

M. F. Ellmore of the Department of Dairy Science, Virginia Polytechnic Institute was elected to the Graduate Studies and Degrees committee of the Agricultural Faculty at its May meeting. G. C. Graf, Head of the Department of Dairy Science, was elected as the Agricultural Faculty representative on the Virginia Polytechnic Institute Advisory Committee on Academic Freedom and Tenure at the same meeting.

George G. Green, with his graduate work at Texas Agricultural and Mechanical College, was appointed Associate Professor of Animal Husbandry, Virginia Polytechnic Institute, to replace Owen Thomas, III, who resigned to be Secretary of the Virginia Hereford Association.

Charles R. Cooper, Assistant County Agent, Franklin, Virginia, was appointed Assistant Professor of Animal Husbandry to do 4-H Extension project work. He replaces A. N. Huff, who is in the Armed Forces.

E. C. Turner, Jr. and E. M. Raffensperger, Biology Department, Virginia Polytechnic Institute, attended a workshop on the use of systemic insecticides in control of livestock insects at Kansas State College in May. The workshop was sponsored jointly by the United States Department of Agriculture and the Entomological Society of America.

The Virginia Crop Reporting Service participated in a research project sponsored by the U. S. Crop Reporting Board designed to forecast the yield of corn by making objective measurements in sample field plots. Fifty sample corn fields were selected at random with two sample plots likewise selected in each field. Counts and measurements were made monthly beginning in late July. Corn in the sample plots was harvested and weighed when mature and sample ears taken for moisture content and shell-out percentage. A post-harvest check was made to determine harvesting loss. Results indicate that an accurate forecast of yield per acre can be made as early as September 1 with a small sample.

Recent additions to the staff of the Division of Chemistry and Foods, Virginia Department of Agriculture, are: Raymond B. Ashworth (University of Georgia), Jesse E. Swann, Thomas E. Marek and Charles E. O'Rear (Virginia Polytechnic Institute), A. Gregory Howe (University

# Quality

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of North Carolina) and Meade F. Kientz (Madison College).

K. W. King of the Department of Biochemistry and Nutrition and the Department of Biology joined a nutritional survey team in Haiti late in May to assess the nutritional and health status of rural people in Haiti. Nutritional surveys have been made in Korea, the Phillipines, Iran, Pakistan, Turkey, Libya, and Guatemala. Last summer, C. J. Ackerman, also of the Department of Biochemistry and Nutrition, served with the team in Libya. The Virginia Academy of Sciences has provided Dr. King with additional funds for sending samples of Haitian soils, insects, and plants to several researchers at Virginia Polytechnic Institute. These samples will be used in the research programs of R. W. Engel and N. O. Price of Biochemistry and Nutrition, C. I. Rich in Agronomy, E. C. Turner and W. G. Evans in Entomology, and P. C. Holt, W. E. Moore, and W. W. Scott in Biology.

Russell F. Miller of the Department of Biochemistry and Nutrition has been elected to membership in the American Institute of Nutrition. He is the second faculty member in the history of Virginia Polytechnic Institute to be honored. Election to the society was in recognition to his basic researches of the mineral nutrition of laboratory and farm animals which clarified the nutritional interactions of molybdenum, copper, and sulfur in the diet and the fate of dietary fluorine.

—Carl Allen, *Virginia Polytechnic Institute*

## ASTRONOMY, MATHEMATICS, PHYSICS

Stephen Berko of the Physics Dept. of the University of Virginia has been awarded a Sloane Foundation Fellowship for the coming academic year. He will be at the Niels Bohr Institute in Copenhagen.

James Hollinger and A. J. Zuchelli, presently graduate students at University of Virginia will study in England next year. Dr. Zuchelli will be at the University of Birmingham as a National Science Foundation Post-Doctoral Fellow, and Mr. Hollinger will attend Cambridge University on a Fulbright Fellowship.

Miss Isabel Boggs will retire this June after thirty-eight years of service in the Physics Dept. of Randolph-Macon Woman's College. Her new address is 14 Parkmont Apts., Lynchburg.

Gordon Stipe is leaving the state to accept a position as Associate Professor of Physics at Boston University. He has been at Randolph-Macon for several years.

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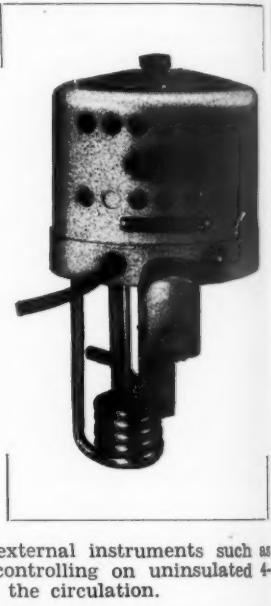

**PNEUMATIC CONTROL**—In the Tempunit, a bimetallic helical sensing element operates a unique pneumatic capsule, which receives its air supply through suction from the stirrer. A temperature indicator is attached to the end of the bimetallic helix. A differential within +0.05°C is attained over the entire range from room temperature to 90°C (195°F) in a 4-gallon tank with no insulation.

There are no fragile glass components in this control system, and no electronic tubes to replace. Pneumatic control is inherently safe. If damage is done to the circulating system, or if overheating should occur, the controlling diaphragm collapses and the heater is switched off.

**CAN CIRCULATE 1 LITER PER MINUTE** to external instruments such as refractometers and viscosimeters while closely controlling on uninsulated 4-gallon water bath. The 6-bladed stirrer produces the circulation.

**STIRRER HAS NO SUBMERGED BEARINGS:** Vertical mounting of the motor reduces to a negligible value the load upon its bearings, which are oil-impregnated. The shaded pole, 1/20-HP motor is brushless and fan-cooled. It is constructed for continuous operation of the stirrer. For 115 volts, 60 cycles AC.

**1,000-WATT IMMERSION HEATER** is of the tubular type wound in the shape of a helix. The stirrer rotating inside the heating coil effectively dissipates heat. A magnesium oxide coating makes the heater capable of operating at temperatures far above the range of the Tempunit. Large capacity of the heater enables rapid heating of water bath from room temperature to set point without excessive overshoot.

**EASILY ATTACHED TO ANY CONTAINER**, small or large, by fiber-cushioned clamp. Weight of the Tempunit is only 6¼ lbs., and its overall length is only 10 inches. Case dimensions are 5½ x 4½ x 3½ inches.

No. RE414-60 TEMPUNIT, each ..... **$135.00**

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The new Physical Science Building at Lynchburg College will be ready for occupancy this fall. It will house the departments of Mathematics, Physics, Chemistry, and Biology.

Randolph Early will join the Physics Department of Lynchburg College in September, as an instructor.

Billy Sloope of the Physics Dept., University of Richmond has been promoted to Associate Professor.

T. E. Gilmer of Hampden-Sydney College will be associate director of the NSF Summer Institute for high school teachers at Converse College.

W. T. Joyner, has joined the staff of Hampden-Sydney College as Assistant Professor of Physics. He is a graduate of Hampden-Sydney and received his graduate training at Duke University.

J. W. Sherman, III, will join the Hampden-Sydney faculty in the fall as Instructor in Mathematics and Physics.

Dorothy Montgomery will be on sabbatical leave from Hollins College during the coming year. She will be at Massachusetts Institute of Technology to work with Dr. Facharias and the committee on secondary school teaching of physics supported by the NSF. Her particular interest is in the preparation of film strip material.

I G. Foster, *Dept. of Physics, Virginia Military Institute*

## BACTERIOLOGY SECTION

The Virginia Branch of the Society of American Bacteriologist will assist students and science teachers in planning projects and giving guidance in the area of microbiology for participants in the exhibits of the Junior Academy. In order to emphasize its interest, the Section has established an award of $25.00 and a certificate for the outstanding exhibit or scientific paper on microbiology presented at the annual meeting of the Junior Academy of Science. This year two awards were given: First Prize, Billy Ridenour (sponsored by Mrs. R. B. Painter) of the William Fleming High School in Roanoke for "Induced mutations of *E. coli* by metabolic substitution"; Second Prize, Betsy Gilfoyle (sponsored by Mrs. Elizabeth Charlton) of the York High School in Yorktown for "Bacteriological study from one station on the York River".

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## ENGINEERING SECTION

A new engineering building now being constructed at Virginia Polytechnic Institute will house Aeronautical and Chemical Engineering Departments, giving each substantially more space than is now available. R. W. Truitt of the Aeronautical Engineering Department has announced that a Stability Wind Tunnell having a 6-foot throat and capable of reaching air velocities of 360 miles per hour has been obtained from the Langley Field Laboratory of NACA and will be set up as part of this building. In addition, a collection of airplane models worth $50,000 was obtained from this source. Professors Truitt and Arthur C. Bruce attended the annual meeting of the Institute of Aeronautical Sciences in New York. Professor Bruce has been awarded a fellowship for further study at the Massachusetts Institute of Technology beginning in September.

Frank C. Vilbrandt of the Chemical Engineering Department at Virginia Polytechnic Institute attended the meeting of University Representatives of the Oak Ridge Institute of Nuclear Studies in May. Nelson F. Murphy of the Chemical Engineering Department attended the national convention of the American Electroplater's Society in May as the delegate of the Blue Ridge Branch of the society.

Tilton E. Shelburne of the Virginia Council for Highway Investigation and Research attended meetings of the Performance Rating Panel and of the National Advisory Committee on the AASHO Road Test in April at La Salle, Illinois. Mr. Shelburne is a member of the Steering Committee of the First International Skid Prevention Conference and attended a meeting of this committee in Washington in May. This Conference will be held at the University of Virginia in September and will attract specialists in this field from many foreign countries. Mr. Shelburne also attended meetings of the department chairmen of the Highway Research Board and of presidents and secretaries of District Six of the American Society of Civil Engineers.

Dean Lawrence R. Quarles of the University of Virginia, School of Engineering was the representative of the Governor of Virginia at a meeting of the Advisory Council on Nuclear Energy of the Southern Regional Education Board held in April. He attended the national meeting of the Institute of Radio Engineers in New York in March, as did Orville R. Harris, also of the University of Virginia. Professors Quarles and Harris are on the By-Laws Committee of the newly-formed Virginia Section of the IRE, and Dean Quarles is also on the Nominating Committee.

Otis L. Updike of the Chemical Engineering Department of the

University of Virginia has served as chairman of the local section of the Society of Sigma Xi during the past academic year. He has been appointed to a sub-committee on Systems Engineering of the American Institute of Chemical Engineers and is working on the organziation of a symposium on this subject to be held at a forthcoming meeting of this society. R. M. Hubbard of the Chemical Engineering Department is serving as chairman of a sub-committee of the American Institute of Chemical Engineers on Teacher Recruiting and Placement.

—Robert M. Hubbard, *University of Virginia*

### PSYCHOLOGY SECTION

William M. Hinton of Washington and Lee University will be teaching at the University of Virginia again this summer and will offer a course at the Virginia Military Institute during the session 1958-1959.

—John K. Bare, *William and Mary*

### STATISTICS SECTION

The following have completed their requirements for the masters degree in statistics at the Virginia Polytechnic Institute: Mr. W. A. Glenn and Miss Suzanne Glass. Miss Glass is now teaching mathematics at Roanoke College. Ronald E. Walpole completed requirements for the doctorate in statistics at the Virginia Polytechnic Institute and is now head of the Mathematics Department at Roanoke College.

Ralph A. Bradley will attend the Gordon Research Conference in July and he has been invited to present a paper at the ISI meeting in Brussels in September. He will also speak to other societies in Europe.

Recent publications in the Department of Statistics of the Virginia Polytechnic Institute include: (1) Statistical Properties of Inverse Gaussian Distributions. II. by M. C. K. Tweedie, *Annals of Mathematical Statistics*. (2) The Comparison of the Sensitivities of Similar Experiments: Theory. by D. E. W. Schumann and R. A. Bradley, *Annals of Mathematical Statistics*. (3) The Comparison of the Sensitivities of Similar Experiments: Applications. by R. A. Bradley and D. E. W. Schumann, *Biometrics*.

Boyd Harshbarger, President of the Biometric Society, ENAR, will attend the international meetings of the Biometric Society in Ottawa in August. Dr. Harshbarger will also attend the meetings of the Regional Committee on Statistics, of which he is Chairman, at Oklahoma State University in June.

—Clyde Y. Kramer, *Virginia Polytechnic Institute*